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## (54) Receiver for receiving Digital Audio Broadcast programmes and FM broadcast programmes comprising Radio Data System signals

(57) A digital broadcast receiver includes an FM receiver including an RDS decoder, a DAB receiver and a controller for comparing the receive state of the FM receiver and that of the DAB receiver and controlling output regenerated by either receiver showing the more satisfactory receive state as the output of the above digital broadcast receiver, and is characterized in that the above controller is provided with first evaluation means for evaluating the receive state of the FM receiver based upon the block error rate of RDS data, second evaluation means for evaluating the receive state of the DAB receiver based upon the frame error rate of audio frames included DAB data and comparison means for comparing the result of evaluation by the first evaluation means and the result of evaluation by the second evaluation means.

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## Description

**[0001]** The present invention relates to a digital broadcast receiver, particularly to a receiver for receiving digital audio broadcast (DAB) which is already at a practical stage in Europe.

**[0002]** For a system for sending or receiving a broadcast wave provided with a data signal according to a predetermined format including a digital audio signal, there is a digital audio broadcast (hereinafter called DAB) system determined by Eureka 147 project. In DAB, one ensemble is composed of plural services and each service is also composed of plural components such as English and German.

**[0003]** Fig. 5 shows an example of the configuration of service in the DAB system and shows a link among services constituting an ensemble 1 (three in Fig. 5), each component (six in Fig. 5) and an orthogonal frequency division multiplex (OFDM) signal actually transmitted from a DAB station.

**[0004]** An OFDM signal transmitted from a DAB station is divided into a fast information channel (FIC) and a main service channel (MSC).

**[0005]** Each subchannel (Subchannels 1 to 63) constituting MSC corresponds to the above each component, and the information of services available in the ensemble and information showing a link among services, components and subchannels are included in the FIC.

**[0006]** Therefore, in DAB, if an ensemble is received, information related to plural services and components included in the ensemble can be acquired and the current service or component can be instantaneously switched to a different service or component without changing a received frequency.

**[0007]** For one of the usage of a DAB receiver for receiving DAB, a function for following the service of a frequency-modulation (FM) station providing the same program can be given. Explaining the above function below, in DAB, the information of an FM station broadcasting the same program as a program being received may be included in the FIC. For example, the identification information and the frequency information of an FM station broadcasting the same program are included.

**[0008]** Therefore, the FM station broadcasting the same program can be detected by extracting the above information from FIC and controlling a radio data system (RDS) receiver based upon the information.

**[0009]** The receiving state of the DAB receiver is compared with that of the RDS receiver. When deterioration of the receiving state of the DAB receiver is detected, the reproduction output is switched to an audio output of the RDS receiver which receives an FM station broadcasting the same program. This function is called "service following". Thus, satisfactory audio reproduction can be maintained.

**[0010]** In the meantime, in DAB, the bit rate of audio information and the protection level of transmission (1 to 5) can be defined in the FIC for each subchannel.

**[0011]** A protection level indicates strength against an error during transmission (as the larger a digit is, the higher an encoding rate is, redundancy becomes low and becomes weak for an error), and an encoding rate based upon convolutional encoding and the sampling of a part of a signal after encoding is defined according to a protection level. In DAB, an average code rate acquired based upon the bit rate of audio information and a protection level is defined so that it is between 0.34 and 0.75.

**[0012]** In the above service following, the more satisfactory receiving state of either a DAB signal or an FM signal is selected and both receiving states are required to be compared. However, as an FM receiver and a DAB receiver adopt different transmission formats, it is difficult to evaluate the receiving state of a received DAB signal and the receiving state of a received FM signal according to the same criterion. As a result, the reliability of the result of comparison cannot be enhanced.

**[0013]** For a method of detecting the receiving state of an FM receiver, parameters such as receive field intensity and the strain component (the high-frequency component) of the phase detection output are already known. For a DAB receiver, it is estimated that a parameter such as an error rate calculated by comparing data before and after Viterbi decoder is used. However, an optimum parameter in comparing the receiving state of a DAB signal and that of an FM signal is not definitely defined yet and room for examination and improvement is left.

**[0014]** Therefore, an object of the present invention is to enhance the reliability of the result of comparison between the receive state of a DAB signal and that of an FM signal.

**[0015]** According to a first aspect of the present invention, there is provided a digital broadcast receiver comprising: an FM receiver for receiving FM data; an RDS decoder for decoding RDS data included in the FM data; a DAB receiver for receiving DAB data; first evaluation means for evaluating receiving state of the FM receiver based upon block error rate of RDS data; second evaluation means for evaluating receiving state of the DAB receiver based upon frame error rate of audio frames included in the DAB data; comparison means for comparing results of evaluation by the first evaluation means and the second evaluation means; and switching means for outputting one of information reproduced by the FM receiver and information reproduced by the DAB receiver based upon comparison result by the comparison means.

**[0016]** According to a second aspect of the present invention, there is provided the digital broadcast receiver according to the first aspect of the invention further comprising calculation means for calculating the block error rate and the frame error rate wherein the number of blocks for calculating the block error rate and the number of frames for calculating the frame error rate are set to be approximately equal.

[0017] According to a third aspect of the present invention, there is provided the digital broadcast receiver according to the first aspect of the present invention wherein the second evaluation means changes the criterion of evaluation based upon protection level information included in the above DAB data.

[0018] According to a fourth aspect of the present invention, there is provided the digital broadcast receiver according to the first aspect of the present invention wherein the second evaluation means changes the criterion of evaluation based upon bit rate information included in the above DAB data.

[0019] In the drawings:

[0020] The above and other objects and features of the present invention will be more apparent from the following description taken in conjunction with the accompanying drawings.

Fig. 1 is a block diagram showing a digital broadcast receiver provided with an RDS receiver according to an embodiment of the present invention;
Fig. 2 is a flowchart executed by a system controller;
Fig. 3 is a table stored in a memory;
Figs. 4A and 4B compares DAB data and RDS data; and
Fig. 5 is an example showing the configuration of services in a DAB system.

[0021] Referring to the drawings, embodiments of the present invention will be described in detail below.

[0022] Fig. 1 is a block diagram showing a digital broadcast receiver provided with an RDS receiver according to an embodiment of the present invention. The above receiver is composed of a DAB receiver for receiving a digital broadcast, an FM receiver for receiving an RDS broadcast, a system controller 1, a switch 2, an amplifier 3, a speaker 4 and a memory 5.

[0023] The DAB receiver includes a front end for DAB (DAB-FE) 11 for tuning to a DAB station, an analog-to-digital (A/D) converter 12 for converting a received analog signal to a digital signal, a fast Fourier transform (FFT) circuit 13 for demodulating an OFDM wave, Viterbi decoder 14 for correcting an error, an audio decoder (a MUSICAM decoder) 15 for decoding compressed audio data (masking pattern adapted universal subband integrated coding and multiplexing (MUSICAM) data) to original audio data and others. As the concrete configuration of each unit is well-known in various documents, it won't be described in detail below. The audio decoder 15 outputs error information of audio frames in received data to the system controller 1.

[0024] The FM receiver includes a front end for FM (FM-FE) 21 for tuning to an FM station, an FM detector 22 for amplifying an intermediate frequency (IF) signal and detecting a composite signal from the IF signal, an RDS decoder 23 for extracting an RDS signal from the composite signal and demodulating it and others. As such configuration is also well-known in various documents, it won't be described in detail below. Further, the FM receiver also outputs block error information of received RDS data to the system controller 1.

[0025] The system controller 1 controls the DAB receiver and the FM receiver, reads the FIC information from the DAB receiver and stores various information data included in such data in the memory 5. Stored information includes the information of services available in an ensemble, information showing a link among services, components and subchannels, information related to FM stations such as PI code and frequency information (FI) list information and others. The system controller 1 outputs a read PI code and read FI list information to FM-FE 21 and the RDS decoder 23 so that the FM receiver can receive a signal from a candidate station the service of which is followed.

[0026] The system controller 1 further controls the switch 2. In the concrete, if it is judged that the receiving state of the DAB receiver is more satisfactory than (or approximately equal to) that of the FM receiver, audio information reproduced by the DAB receiver is selectively output and if it is judged that the receiving state of the FM receiver is more satisfactory than that of the DAB receiver, audio information reproduced by the FM receiver is selectively output. The output audio information is amplified by the amplifier 3 and output from the speaker 4. The above description is the outline of the DAB receiver.

[0027] Next, the operation of the system controller 1 according to the present invention will be described in detail. Fig. 2 is a flowchart showing the operation of the system controller 1 in a service following mode. This flowchart shall be executed when an instruction to follow service from a user is input.

[0028] When an instruction to follow service from a user is input, the system controller 1 judges whether the DAB receiver is currently tuned to any ensemble or not in step S1.

[0029] As FIC data can be obtained if the DAB receiver is synchronized with any ensemble, the data is decoded. From the FIC data, the information of the protection level and the bit rate of each subchannel, the information of services available in the ensemble, information showing a link among services, components and subchannels, the information of PI code, FI list information and others out of the above data are extracted and stored in the memory 5 in step S2.

[0030] Afterward, services desired by a user are selected out of the acquired information and output from the speaker 4 in step S3.

[0031] After audio output, the system controller 1 calculates an error rate based upon each error information supplied from the DAB receiver and the FM receiver (step S4). A concrete method of calculating the error rate will be described later.

[0032] Next, the error rate of a DAB signal calculated in step S5 is compared with a reference value. At this time, first, a reference value for evaluating the receiving

state of the currently selected subchannel is selected from the corresponding table stored in the memory 5 based upon the information of the protection level of each subchannel acquired and stored in step S2 and the information of the actually currently selected subchannel.

**[0033]** Fig. 3 shows an example of a table stored in the memory 5. The table is constituted corresponding to a protection level (PL) so that reference values corresponding to protection levels 1 to 5 which can be selected in DAB can be acquired.

**[0034]** For example, if the protection level of the currently selected component is 1, a reference value 1 is defined as the corresponding criterion and is selected as a reference value to be compared.

**[0035]** Next, in the step S5, the defined reference value and an error rate calculated this time are compared. As a result of comparison, as the receiving state of a DAB station is not deteriorated if it is judged in the step S5 that the error rate calculated this time is smaller than the reference value, control is returned to the step S4, the error rate is again calculated based upon error information supplied at that time and is compared with the reference value in the step S5. Therefore, when the receiving state is satisfactory, control itinerates in a loop between the step S4 and the step S5.

**[0036]** In the meantime, as the receive state of the DAB station is deteriorated if it is judged in the step S5 that the error rate calculated this time is larger than the reference value as a result of comparison between the defined reference value and the error rate calculated this time, processing proceeds to step S6 and it is judged whether service to an RDS station broadcasting the same program can be followed or not. In the concrete, a reference value for FM is set as in the step S5, is compared with the error rate of an FM-RDS station and it is judged whether there is an FM-RDS station which broadcasts the same program and the receiving state of which is more satisfactory than that of the DAB station or not.

**[0037]** If it is judged in the step S6 that service can be followed, the switch 2 is controlled to reproduce the audio information of the RDS station.

**[0038]** In the meantime, if it is judged in the step S6 that an RDS station suitable for following service cannot be found, control is returned to the step S4 because service cannot be followed and the monitoring of the receiving states of both receivers is continued. For example, if the receiving state of the FM receiver becomes satisfactory during monitoring, it is judged in the step S6 that service can be followed and the switch 2 is controlled to reproduce the audio information of the RDS station.

**[0039]** The above description is made on the operation of the service following. According to the present invention, when the receiving state of a DAB station is evaluated in the step S5, an optimum reference value for evaluation is determined based on information related to a subchannel being currently selected and the deterioration of receiving state is judged based on the determined reference value. Thus, noises to be heard by the user and the judgement result of deterioration can be always consistent irrespective of the protection level of the selected subchannel.

**[0040]** Next, processing for calculating an error rate executed in the step S4 will be described in detail. In the present invention, for a parameter for evaluating the receiving state of a DAB signal and an FM signal, an error rate detected in each receiver is used. In the concrete, the receiving state of a signal from an RDS station received by the FM receiver is evaluated based upon the block error rate of the received RDS data and the receiving state of a signal from a DAB station received by the DAB receiver is judged based upon the frame error rate of audio data (MUSICAM data) transmitted via a subchannel in the received DAB data. This is based upon the following knowledge.

**[0041]** In Figs. 4A and 4B, audio data respectively transmitted as RDS data and in DAB are compared. Fig. 4A shows the format of audio data in DAB and Fig. 4B shows the format of RDS data.

**[0042]** One group of RDS data is composed of four data blocks of offsets A to D as well-known, RDS is a transmission system in which it can be detected in units of block whether an error occurs or not and the length of one block is equivalent to 22 ms.

**[0043]** In the meantime, audio data in DAB complies with the layer 2 of Moving picture coding experts group (MPEG1), and the length of one frame is equivalent to 24 ms. In addition to the data of each subband, information such as a DAB header, bit allocation information and ScFSI is allocated in the vicinity of the head portion. Further, a cyclic redundancy check (CRC) provided to detect the error of a DAB header, bit allocation information and ScFSI and CRC provided to detect the error of a scale factor are included in the above one frame. Therefore, it can be detected in units of frame (hereinafter called a block as in RDS data for the convenience of explanation) owing to such CRCs whether an error occurs or not.

**[0044]** The applicant considers that the length of one block in both systems is approximately equal, uses the block error rate of audio data to judge the receiving state of a DAB station and uses the block error rate of RDS data to judge the receiving state of an RDS station.

**[0045]** Explaining the above reason, as a temporal error between groups of data used for judgment is kept within approximately 10% between both systems if each number of blocks equivalent to the denominator of a block error rate is set to be approximately equal, each receiving state can be judged on an extremely close condition.

**[0046]** Further, the block error rate of RDS data and heard noise of analog audio information are proportional and the block error rate of RDS and the receiving state of FM audio can be precisely related.

**[0047]** Therefore, the reliability of the result of comparison can be enhanced by comparing the block error rates.

**[0048]** In the above embodiment, both error rates are calculated by the controller 1, however, each error rate may be also calculated respectively by the DAB receiver and the FM receiver. Also, in the above embodiment, the criterion for the evaluation of the receive state of a DAB station is changed based upon the protection level of a subchannel, however, the present invention is not limited to this and an optimum reference value may be also determined based upon the bit rate information of audio data transmitted via a subchannel.

**[0049]** As described above, according to the present invention, as the block error rate of RDS data and the frame error rate of audio frames included DAB data are compared, each receiving state can be judged on an extremely close condition and the reliability of the result of comparison can be enhanced.

**[0050]** The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. The embodiment was chosen and described in order to explain the principles of the invention and its practical application to enable one skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto, and their equivalents.

## Claims

1. A digital broadcast receiver comprising:

   an FM receiver for receiving FM data;
   an RDS decoder for decoding RDS data included in the FM data;
   a DAB receiver for receiving DAB data;
   first evaluation means for evaluating receiving state of said FM receiver based upon block error rate of RDS data;
   second evaluation means for evaluating receiving state of said DAB receiver based upon frame error rate of audio frames included in the DAB data;
   comparison means for comparing results of evaluation by said first evaluation means and said second evaluation means; and
   switching means for outputting one of information reproduced by said FM receiver and information reproduced by said DAB receiver based upon comparison result by said comparison means.

2. The digital broadcast receiver according to Claim 1, further comprising calculation means for calculating the block error rate and the frame error rate wherein the number of blocks for calculating the block error rate and the number of frames for calculating the frame error rate are set to be approximately equal.

3. The digital broadcast receiver according to Claim 1, wherein said second evaluation means changes the criterion of evaluation based upon protection level information included in said DAB data.

4. The digital broadcast receiver according to Claim 1, wherein said second evaluation means changes the criterion of evaluation based upon bit rate information included in said DAB data.

FIG. 1

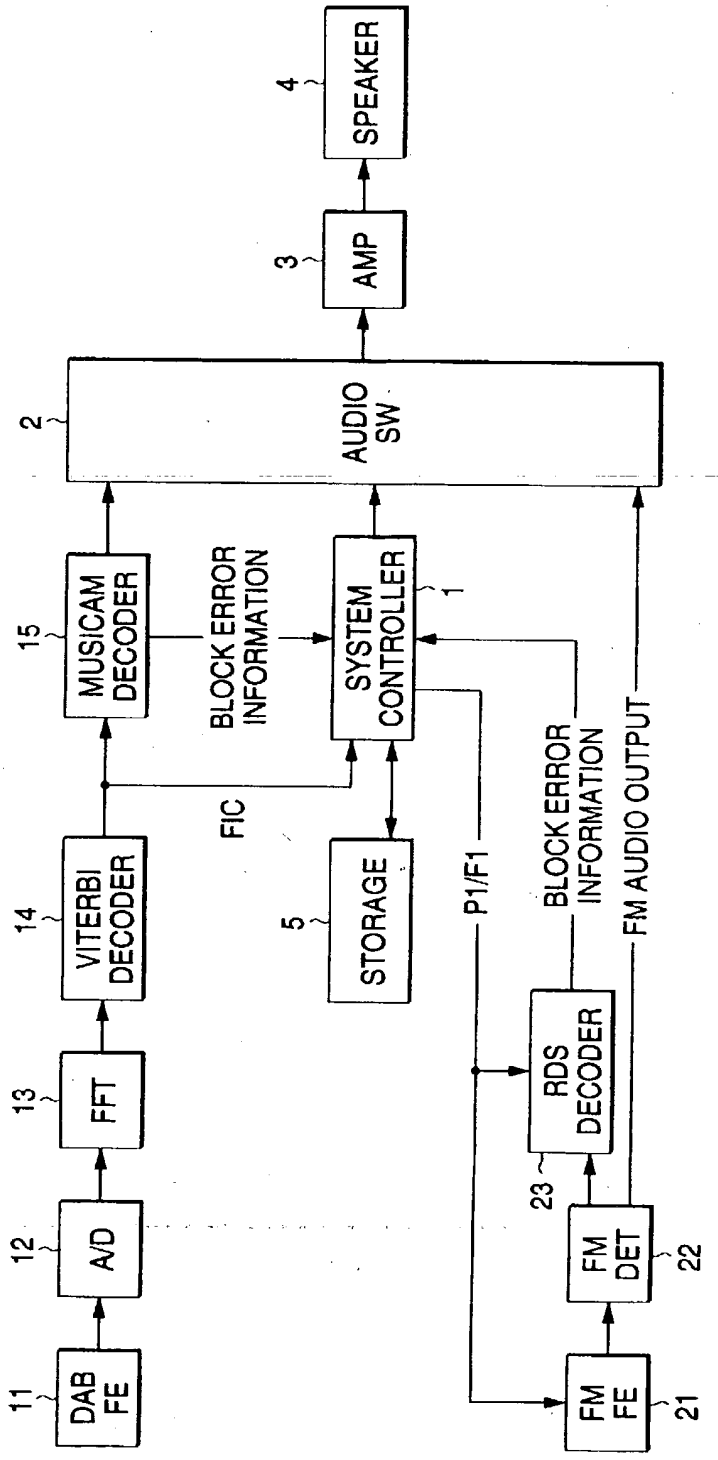

4
SPEAKER
3
AMP
2
AUDIO SW
15
MUSICAM DECODER
BLOCK ERROR INFORMATION
SYSTEM CONTROLLER
1
FIC
14
VITERBI DECODER
5
STORAGE
P1/F1
BLOCK ERROR INFORMATION
FM AUDIO OUTPUT
13
FFT
RDS DECODER
23
12
A/D
FM DET
22
11
DAB FE
FM FE
21

FIG. 2

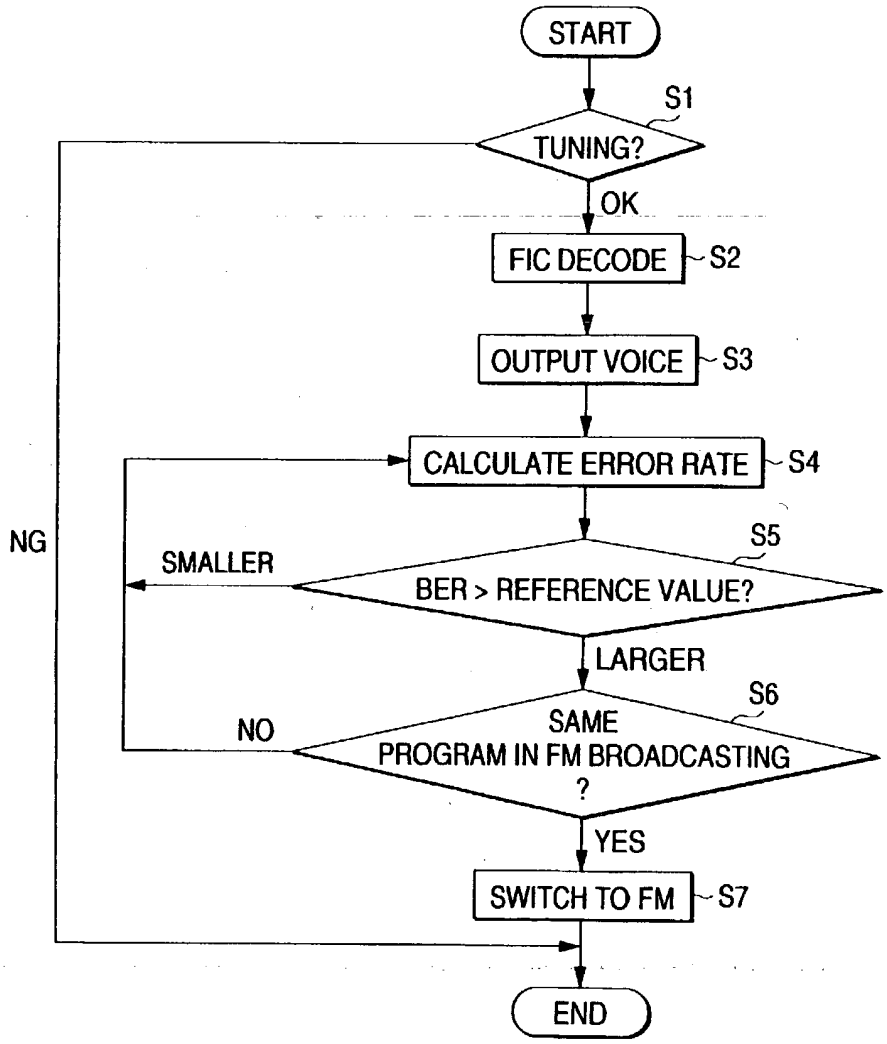

START
S1
TUNING?
NG
OK
FIC DECODE
S2
OUTPUT VOICE
S3
CALCULATE ERROR RATE
S4
S5
SMALLER
BER > REFERENCE VALUE?
LARGER
S6
NO
SAME PROGRAM IN FM BROADCASTING ?
YES
SWITCH TO FM
S7
END

FIG. 3

| PL | REFERENCE VALUE |
|---|---|
| 1 | REFERENCE VALUE 1 |
| 2 | REFERENCE VALUE 2 |
| 3 | REFERENCE VALUE 3 |
| 4 | REFERENCE VALUE 4 |
| 5 | REFERENCE VALUE 5 |

FIG. 4A

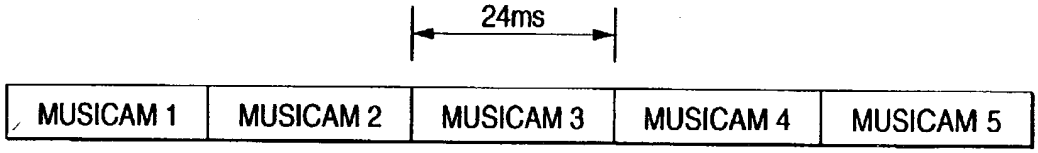



FIG. 4B

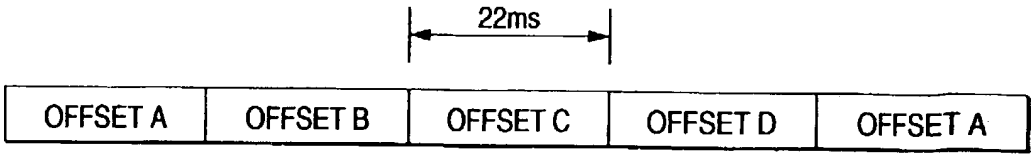
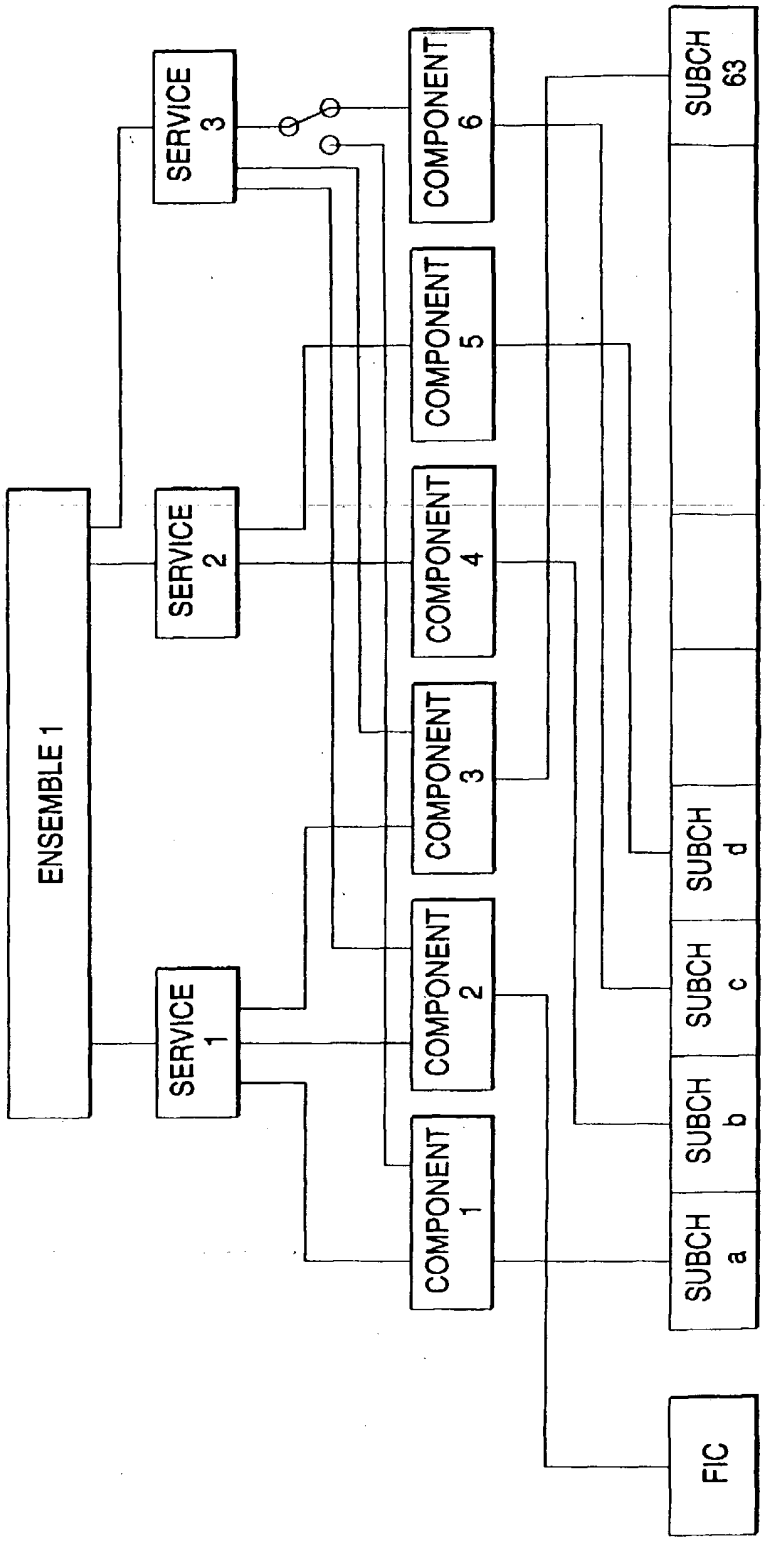


FIG. 5


ENSEMBLE 1
SERVICE 1
SERVICE 2
SERVICE 3
COMPONENT 1
COMPONENT 2
COMPONENT 3
COMPONENT 4
COMPONENT 5
COMPONENT 6
FIC
SUBCH a
SUBCH b
SUBCH c
SUBCH d
SUBCH 63
MSC